Insulation and Jacket Materials

Purpose

Conductors need to be electrically isolated from other conductors and from the environment to prevent short circuits. **Insulation** is applied around a conductor to provide this isolation. Most wire and cable insulations consist of polymers (plastics) which have a high resistance to the flow of electric current. A **jacket** is the outermost layer of a cable whose primary function is to protect the insulation and conductor core from external physical forces and chemical deterioration.

Types and Applications

Thermoplastics

Polyvinyl Chloride (PVC)
Sometimes referred to simply as "**vinyl,**" PVC does not usually exhibit extremely high and low temperature properties in one formulation. Certain formulations may have a −55°C to 105°C rating, while other common vinyls may have a −20°C to 60°C rating. The many varieties of PVC also differ in pliability and electrical properties. The price range can vary accordingly. Typical dielectric constant values range from 3.5 to 6.5.

When properly formulated, **thermoplastic jackets** of polyvinyl chloride (PVC) provide cables with the ability to resist oils, acids, alkalis, sunlight, heat, weathering, and abrasion. This range of properties makes PVC a suitable outer covering for such cable types as underground feeders (**Type UF**), control, aerial, street lighting, and cables for direct burial.

PVC is frequently used as an impervious jacket over and/or under metal armor where the installation requires PVC's protective characteristics. **Flamarrest** is a plenum grade, PVC-based jacketing material with low smoke and low flame spread properties. **Plenum rated cables** jacketed with Flamarrest meet **UL Standard 910.**

Fluoropolymers
Fluoropolymers, with the exception of **TFE Teflon**, are extrudable thermoplastics used in a variety of low voltage insulating situations. Fluoropolymers contain fluorine in their molecular composition which contributes to their excellent thermal, chemical, mechanical, and electrical characteristics. The most commonly used fluoropolymers are: **Teflon** (**TFE**, **FEP**, and **PFA**), **Tefzel** (**ETFE**), **Halar** (**ECTFE**), and **Kynar** or **Solef** (**PVDF**).

Teflon
Teflon has excellent electrical properties, temperature range, and chemical resistance. It is not suitable where subjected to nuclear radiation and does not have good high voltage characteristics. FEP Teflon is extrudable in a manner similar to PVC and polyethylene. This means that long wire and cable lengths are available. TFE Teflon is extrudable in a hydraulic ram type process. Lengths are limited due to amount of material in the ram, thickness of the insulation, and preform size. TFE must be extruded over a silver- or nickel-coated wire. The nickel- and silver-coated designs are rated 260°C and 200°C maximum, respectively. The cost of Teflon is approximately 8 to 10 times more per pound than PVC compounds.

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Teflon TFE is the original Teflon resin invented by DuPont in 1938. It is an opaque, white material although some forms are translucent in thin sections. It does not melt in the usual sense. To coat wire for insulating purposes, Teflon TFE is extruded around the conductor as a paste, then sintered. Conductors can also be wrapped with tape of Teflon TFE. Maximum continuous service temperature of Teflon TFE is 500°F (250°C).

Specific advantages of wire insulated with Teflon TFE include:

- non-flammability
- extremely high insulation resistance
- very low dielectric constant
- small size compared to elastomer insulated wires
- excellent lubricity for easier installation
- chemically inert

Teflon FEP was also invented by DuPont and became commercially available in 1960. It has a glossy surface and is transparent in thin sections. Teflon FEP is a true thermoplastic. Wire insulated with Teflon FEP can be melt extruded by conventional methods. Maximum continuous service temperature is 400°F (205°C). Teflon FEP is an excellent nonflammable jacketing material for multiconductor cables.

Specific advantages of wire insulated with Teflon FEP include:

- high current carrying ability (ampacity)
- easily color coded
- smallest diameter of any high temperature wire
- nonflammable
- very low moisture absorption

Tefzel (**ETFE**) is commonly used in computer backplane wiring and has the highest abrasion and cut-through resistance of any fluoropolymer. Tefzel is a thermoplastic material having excellent electrical properties, heat resistance, chemical resistance, toughness, radiation resistance, and flame resistance. Tefzel's temperature rating is −65°C to 150°C.

Halar (**ECTFE**) is similar to Tefzel and is also used in wirewrap applications, but since it is less expensive than Tefzel, it is often used as insulation on multipair plenum telephone cables. It has a maximum operating temperature of 125°C (UL). Halar has excellent chemical resistance, electrical properties, thermal characteristics, and impact resistance. Halar's temperature rating is −70°C to 150°C.

Kynar (**PVDF**) is one of the least expensive fluoropolymers and is frequently used as a jacketing material on plenum cables. Because of its high dielectric constant, however, it tends to be a poor insulator. PVDF has a temperature maximum of 135°C (UL).

Polyolefins (PO)
Polyolefin is the name given to a family of polymers. The most common polyolefins used in wire and cable include: polyethylene (PE), polypropylene (PP), and **ethylene vinyl acetate (EVA).**

Polyethylene (PE)
Polyethylene has excellent electrical properties. It has a low dielectric constant, a stable dielectric constant over a wide frequency range, and very high insulation resistance. However, polyethylene is stiff and very hard, depending on molecular weight and density. **Low density PE** (**LDPE**) is the most flexible, with high-density, high-molecular weight formulations being least flexible. Moisture resistance is excellent. Properly formulated PE has excellent weather resistance. The **dielectric constant** is 2.3 for solid and 1.6 for cellular (foamed) insulation. Flame retardant formulations are available, but they tend to have poorer electrical properties.

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Polypropylene (PP)
Similar in electrical properties to polyethylene, this material is primarily used as an insulation material. Typically, it is harder than polyethylene. This makes it suitable for thin wall insulations. The UL maximum temperature rating may be 60°C or 80°C, but most UL styles call for 60°C maximum. The **dielectric constant** is typically 2.25 for solid and 1.55 for cellular designs.

Thermoplastic Elastomer (TPE)
TPE, sometimes called **TPR** (**thermoplastic rubber**), has excellent cold temperature characteristics making it an excellent insulating and jacketing compound in cold climates. It is resistant to aging from sunlight, oxidation and atmospheric ozone. It retains most of its physical and electrical properties in the face of many severe environmental conditions such as a salt water environment. TPE compounds can be rated as high as 125°C (257°F).

TPE has good chemical resistance to all substances except hydrocarbons. It has a tendency to swell in a hydrocarbon environment, causing the material to degrade. It has good abrasion resistance. It will resist wear, cutting, and impact. These properties make TPE jackets an excellent choice for use in control cables that are dragged around or frequently moved.

TPE compounds are used as insulating materials up to a 600 volt rating. The most common cables using TPE insulation are portable control cables such as SEO and SJEO.

Polyurethane (PUR)
Polyurethane is used primarily as a cable jacket material. It has excellent oxidation, oil, and ozone resistance. Some formulations also have good flame resistance. It has excellent abrasion resistance. It has outstanding “memory” properties, making it an ideal jacket material for **retractile cords.**

Thermosets

Chlorinated Polethylene (CPE)
Chlorinated polyethylene is a crosslinked synthetic rubber with outstanding physical and electrical properties for many cable jacket applications. It is highly resistant to cold flow (compression set) and other forms of external loading as well as heat, light, and chemical attack.

CPE compares favorably with most other currently used synthetic elastomers used for cable jacketing. It is resistant to ozone and ultraviolet (sunlight) degradation. Properly compounded, CPE will withstand prolonged immersion in water. It will not support combustion, but under the right conditions of excessive heat, oxygen supply, and flame source it will burn slowly. Removal of the ignition source will extinguish the flame. CPE jacketed cables pass the IEEE 383, UL, CSA, and ICEA flame tests.

CPE maintains its flexibility at −18°C (0°F) and does not become brittle at −40°C (−40°F). Its low temperature impact resistance is excellent. CPE jackets are suited to 149°C (300°F) and intermittently to higher temperatures. They will maintain adequate flexibility after repeated aging at elevated temperatures. They are known for abrasion resistance and long life in mining cable applications. CPE does not support the growth of mold, mildew, or fungus.

CPE is resistant to most strong acids and bases and many solvents except for chlorinated organics. It is particularly well-suited to chemical plant use where both above ground (ultraviolet and flame retardancy) and below ground (water and chemical resistance) properties are desired. CPE’s resistance to oils and fuels is good. CPE can be conveniently colored over a wide range and will maintain color upon aging.

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Neoprene (CP)
Neoprene is a vulcanized synthetic rubber. It provides a resilient jacket that resists permanent deformation under heat and load, and does not embrittle at low temperatures. It is highly resistant to aging from sunlight and oxidation, and is virtually immune to atmospheric ozone.

Samples of neoprene-jacketed cable, tested outdoors under constant exposure for 40 years, have remained tough, resilient, uncracked, and completely serviceable. Neoprene jackets are "flame resistant," i.e., not combustible without directly applied heat and flame. Neoprene will burn slowly as long as an outside source of flame is applied, but is self-extinguishing as soon as the flame is removed. Neoprene-jacketed power cable can be flexed without damage to the jacket at −40°C (−40°F) and will pass a mandrel wrap test down to about −45°C (−50°F). Neoprene jackets resist degradation for prolonged periods at temperatures up to 121°C (250°F). Satisfactory performance at even higher temperatures is possible if the exposures are brief or intermittent.

Neoprene jackets have excellent resistance to soil acids and alkalis. Mildew, fungus, and other biological agents do not deteriorate properly compounded neoprene. These jackets perform well in many chemical plants. They are tough, strong, resilient, and have excellent resistance to abrasive wear, impact, crushing, and chipping. Because of these properties, neoprene is the jacketing material frequently used for mine trailing cables and dredge cables.

Neoprene's oil resistance was an important factor in its early adoption as a superior jacketing material for industrial-type portable cords, cables, and automotive ignition wire. It gives excellent protection against lubricating oils, grease, animal and vegetable fats, and oils. The electrical properties of neoprene are sufficient to permit its use as an insulation for 60 Hz current at 600 V and below.

Crosslinked Polyethylene (**XLP** or **XLPE**)
Crosslinked Polyethylene is a frequently used polymer in wire and cable. It is most often used as the insulation of 600 volt building wire (e.g., **Type XHHW**), as the insulation in 5 to 69 kV and higher rated power cables, and as the insulation in many control cables.

XLP has very high insulation resistance (IR), high dielectric strength, and low **dielectric constant** (2.3). It also is a very tough material at temperatures below 100°C so it is resistant to cutting, impact, and other mechanical forces. Its low temperature performance is also very good down to −40°C and below. XLP's fire resistance, however, is poor unless flame retardants are added. XLP is lower in cost than EPR.

Ethylene Propylene Rubber (**EP**, **EPR**, or **EPDM**)
Ethylene Propylene Rubber is a common synthetic rubber polymer used as an insulation in electrical wire and cable. EPR is used as the insulation in 600 volt through 69 kV power cables, as an integral insulation/jacket on welding cables, and as an insulation in many cords, portable mining cables, and control/instrumentation cables.

Because of its rubber-like characteristics, EPR is used in many highly flexible cables. Its dielectric strength is good but not as high as that of PE or XLP. **Dielectric constant** ranges from 2.8 to 3.2 depending on the specific EPR formulation. EPR is abrasion resistant and is suitable for use at temperatures down to −60°C. It is fairly flame retardant and can be made even more flame retardant by careful formulation. Flame retardant versions are often referred to as "**FREP**" or "**flame retardant EP**." EPR's high temperature characteristics are very good. Some formulations can withstand continuous temperatures as high as 150°C.

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Hypalon (CSPE)
Hypalon is a thermosetting, crosslinked, chlorosulphonated polyethylene made by DuPont with many excellent physical and electrical properties. It is inherently resistant to cold flow (compression set) resulting from clamping pressures and other forms of external loading; it is immune to attack by ozone; and it is highly resistant to aging from sunlight and oxidation. Water absorption of properly compounded Hypalon cable sheathing is extremely low.

Hypalon sheathing will not support combustion. It will burn slowly as long as an outside source of flame is applied but is self-extinguishing as soon as the flame is removed. It remains flexible at −18°C (0°F) and will not become brittle at −40°C (−40°F). Hypalon jacketed constructions pass both the Underwriters Laboratories' vertical flame test and the U.S. Bureau of Mines' flame test for mining cable.

At high temperatures Hypalon will perform satisfactorily after short-term exposure at up to 148°C (300°F)—even higher if compounded for maximum heat resistance. It is well-known for its resistance to chemicals, oils, greases, and fuels. It is particularly useful as a cable sheathing in plant processing areas, where airborne chemicals attack ordinary jacketing materials and metal conduit.

Hypalon surpasses most elastomers in resistance to abrasion. It is highly resistant to attack by hydrocarbon oils and fuels. It is especially useful in contact with oils at elevated temperatures. Sheathing of Hypalon provides high resistance to impact, crushing, and chipping. Hypalon's electrical properties make it appropriate as insulation for low-voltage applications (up to 600 volts) and as jacketing for any type of wire and cable.

Silicone
Silicone is a soft, rubbery insulation which has a temperature range from −80°C to 200°C. It has excellent electrical properties plus ozone resistance, low moisture absorption, weather resistance, and radiation resistance. It typically has low mechanical strength and poor scuff resistance.

Fibrous Coverings

Fibrous coverings are commonly used on high temperature cables due to their excellent heat resistance. They are normally constructed of a textile braid (i.e., **Fiberglass** or **K-fiber**) impregnated with a flame and heat resistant finish.

K-Fiber insulating materials are a blend of **polyaramid, polyamid, phenolic-based** and **fiberglass fibers.** They are available as roving and yarn for insulating applications and as rope for use as fillers. They provide a non-asbestos, abrasion-, moisture-, flame- and temperature-resistant, non-melting insulating material for all applications requiring a 250°C (482°F) temperature rating which would have previously utilized asbestos.